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CONTENTS

	PAGE
The Iberia Heat Tolerance Test	161
The Iberia Heat Tolerance Test for Cattle ...	162
Biennial Bearing in Cacao	164
Oil from the Sunflower	165
Some Problems of Cacao Fermentation ...	166
Witches' Broom Disease Investigations ...	170
Experiments on Ridged Cultivation in Tanganyika and Nigeria	177
Manganese Deficiency	179
Use of Corn Binder for Harvesting Forage Crops	179
Chemical Notes	180

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THE IBERIA HEAT TOLERANCE TEST

The history of livestock in the tropics during the last hundred years contains many records of attempts to improve the productivity of indigenous stock by cross-breeding with select stock of exotic origin. In addition, attempts have been made to acclimatize stock of non-tropical origin. By the costly process of trial and error certain procedures were found to succeed, others to fail but in many cases a large element of doubt remained. Assessment of the potentialities of such stock, containing different amounts of blood from various exotic breeds, is difficult owing to the multiplicity of variables and only lengthy study of reasonably large numbers of animals allows evaluation of the worth of different breeding policies.

Whether an animal is of agricultural value in a given environment depends, fundamentally, on the degree of adaptability of its physiological functions. At present research in animal husbandry suffers from a lack of objective methods for assessing adaptability and the Iberia Heat Tolerance Test, elaborated by Rhoad as an outcome of a series of studies of tropical cattle and described in an article published in this issue, is a valuable contribution. That the test needs no elaborate apparatus is an advantage.

The warm-blooded animal maintains a constant internal temperature by regulating the transfer of heat to its external environment. The mechanisms whereby this heat, which arises through the processes of metabolism from the ration, are dissipated are, mainly, by radiation and conduction to the environment and by vaporization from the skin surface and the lungs. At high temperature the losses by radiation become quantitatively less, in fact with exposure to direct sunlight heat may even be gained. This places a greater burden on the organism to dispose of the heat arising from its metabolic processes by vaporization of water. If, however, the moisture content of the atmosphere rises coincident with the increased environmental temperature, as in the wet tropics, heat disposal by vaporization is in turn impeded. The result, if conditions are severe enough and if the range of physiological adaptation is limited by genetic constitution, is a rise in body temperature which may be severe enough to cause prostration and death.

It appears that investigation of the adaptability of individuals to these conditions by Rhoad's Test will allow a much earlier assessment of the advisability of certain breeding programmes with a consequent saving in time and expense.

It should be noted that the article by Rhoad is of particular interest in its bearing on observations which were recently published in this journal* on the fertility and milk production of cross-bred cattle.

*Harrison, E. The breeding and artificial insemination of dairy cows in Trinidad, B.W.I. *Tropical Agriculture*, XXI, 1, pp. 3-7, 1944.

THE IBERIA HEAT TOLERANCE TEST FOR CATTLE

BY

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The results of considerable research with cattle in the warm climates have consistently pointed out (1) the necessity of having animals genetically adjusted to the rigours of a tropical environment if development and production are to approach the potential levels of the strains, and (2) that breeds and crossbred types of diverse origin vary widely in their capacity to withstand tropical climatic conditions. A major objective in controlled cattle breeding programmes in the Tropics is to obtain animals adapted to tropical conditions and possessing high productiveness.

There are well established methods of measuring productiveness of cattle. Some are highly complicated and are used only by research workers, others are sufficiently simplified to become part of the regular practices on well managed farms. Measuring adaptability to a tropical environment, however, has only recently been attempted in field laboratory tests. Previous to the field tests, adaptability was determined by observing the results of numerous attempts to establish exotic breeds and their crossbred types in the Tropics. This is the trial and error method that has been going on in a more or less unorganized way for years. The observed results of these attempts have produced important basic information on the types of cattle suitable to the Tropics and to what extent grading-up to the exotic breeds is practicable under given conditions.

Although the trial and error method is still going on and further valuable information may be obtained from this method, there is need for accurate laboratory and field tests to shorten the time and costs required in determining adaptability. It was with these objectives in view that the Iberia Heat Tolerance Test was developed.

Like many tests the Iberia Heat Tolerance Test developed from rather crude beginnings through a phase of somewhat complicated procedure to its present simplified but not necessarily final form. As early as 1936 the writer (Rhoad 1936) reported observations made in the field on the respiratory rate of variously bred dairy cattle at Vicosa, Brazil, and pointed out that cattle of European and Indian origin responded differently to high thermal environments and that their crossbred types responded in an intermediate manner. It was suggested that the metabolic rate of each varied in similar fashion. This work was continued by the writer at the Iberia Livestock Experiment Farm, Jeanerette, Louisiana, with additional observations that included the effects of atmospheric temperatures and humidity on body temperature and water economy of cattle. Water economy was determined by measuring the transpiration of moisture through the skin, the nitrogen concentration of the urine and the per cent. moisture of the faeces. Data were obtained over a wide range of atmospheric temperatures with the cattle held in the shade and also exposed to direct solar radiation. Observations were also made on grazing habits. Significant differences were found between genetic types on all accounts with the exception of the per cent. moisture in the faeces. The results of this work were reported in two papers (Rhoad 1938, 1940) establishing a basis for measuring adaptability of cattle to a high thermal environment.

The method reported above has been used at the Iberia station for several years with satisfactory results. However, it can be applied only where laboratory facilities are available and the number of individuals that can be tested at one time is rather limited. At Jeanerette only nine animals could be tested at one time which, with the necessary repetitions, required all summer to test about 50 head with the assistance of two laboratory technicians.

A simplified method was needed whereby larger numbers could be tested with non-technical assistance and the results recorded in a manner that would facilitate comparison with results obtained in other countries. This was accomplished by modifying the laboratory method (Rhoad 1940) to simplified field or barn test referred to here as the Iberia Heat Tolerance Test.

The test is based on the fact that the various physiological processes related to the efficiency of heat disposal and the various morphological characters that facilitate, or impede, the comfort of cattle in a tropical environment are reflected in the case with which body temperature is controlled. The position of body temperature under prescribed climatic conditions is used, therefore, as a base. As the Iberia Heat Tolerance Test is a procedure to be applied in the field the climatic conditions under which it is made cannot, of course, be standardized in the usual concept of the term but prescribed conditions can readily be met.

At the Iberia Livestock Experiment Farm bright, calm summer days are chosen when the atmospheric temperatures, in the shade, are in the 90 degree Fahrenheit class, that is, between 85 and 95 degrees. The cattle to be tested are placed shortly after sunrise in a temporary, wire-fence corral built over sod. The cattle are free to move about and have water available. At 10 a.m., standard time, 8 to 10 head are placed without undue commotion in a cattle chute close by. Rectal temperatures are taken and recorded. Ordinary clinical thermometers are used, each attached to a tail clamp to avoid undue breakage. While the thermometers are inserted respirations per minute are obtained by observing flank movements. The cattle are then removed from the chute and placed in a holding pen until all animals in the corral have been through the chute after which the entire group is returned to the corral. It requires about 15 minutes to obtain the data on each group while in the chute. At 3 p.m. standard time, the cattle are again placed in the chute in random order and respirations per minute and body temperature again recorded. The cattle are then turned out to pasture for the rest of the day and night. The test is twice repeated on the same group of animals from which the average body temperature and respirations per minute are computed for the three days. Both morning and afternoon data are included in the average. Atmospheric shade temperatures and humidities are recorded at the start of the morning and afternoon tests. Wind velocity is also recorded although this information is not necessary and may be dispensed with.

In the event that the skies become overcast or rain squalls interfere the tests are discontinued for the day. At Jeanerette the afternoon tests are sometimes discontinued for these reasons. It is then necessary to repeat the tests to obtain the afternoon data. If the previous morning test was satisfactory only the afternoon test is required although the animals must have been in the corral since early morning. In determining the average no more than three satisfactory morning and afternoon tests are used although more may be available especially if the tests have been interrupted by change in weather. Usually one day is required to accustom the animals to the procedure. Data from these trial tests are not included in the averages.

Cattle that are halter broken and quiet can be tied to a fence and data obtained without placing them in a corral or chute. It is important, whether tied or placed in a corral, for the animals to be away from buildings or other obstacles that would offer shade or obstruct wind movement. It is also important that they be placed over sod as paved corrals would modify considerably the natural climatic conditions under which the test is made.

The conditions prescribed above are sufficiently severe with low heat tolerant cattle to cause great distress and an occasional animal may have to be removed in the late afternoon to avoid heat stroke.

Following the method outlined above data on as many as 36 head have been obtained in one day.

With the data that accumulate when this test is made on large numbers, a convenient way of expressing the results that would indicate at a glance the heat tolerance of an individual or group is almost necessary. For this purpose a heat tolerance or adaptability co-efficient has been derived from the following formula :

$$100 - \left[10\ (BT - 101.0)\right] \text{ in which:}$$

BT = average body temperature obtained under conditions of the Iberia Test,

101.0 = normal body temperature of cattle,

10 = a factor to convert degrees deviation in body temperature from the normal to a unit basis,

100 = perfect efficiency in maintaining body temperature at 101.0°F.

Using the above formula an individual or group of cattle with an average body temperature of 103.8°F. would have a heat tolerance co-efficient of :—

$$100 - \left[10(103.8 - 101.0)\right] = 100 - \left[10(2.8)\right] = 100 - 28 = 72.$$

With data on 198 animals collected over a three year period and including repeat tests on some individuals each year, the heat tolerance or adaptability co-efficient for variously bred types of cattle that compose the herds of the Iberia station has been determined and is given in table 1.

The average conditions at Jeanerette at the time of the tests were : average a.m. temperature, 90.9°F. ; relative humidity, 82.8% ; and wind 2.1 m.p.h. ; average p.m. temperature, 93.2°F. ; relative humidity, 71.7% ; and wind 4.5 m.p.h.

Table I

Scale of heat tolerance for cattle as determined by the Iberia Heat Tolerance Test, 1944

Breeding	Sex	Numbers animals	Numbers tests	Coefficient of heat tolerance*
Purebred Brahman	F	7	18	89
½ Brahman ½ Angus ...	F	19	67	84
⅜ Brahman ⅝ Angus ...	F	8	21	84
Purebred Santa Gertrudis ...	F	7	21	82
½ Africander ½ Angus	F	22	64	80
Purebred Jersey	F	34	34	79
¼ Brahman ¾ Angus ...	F	54	165	77
Grade Hereford ...	S	12	12	73
¼ Africander ¾ Angus ...	F	4	9	72
Purebred Aberdeen Angus	F	31	69	59

*100 = Perfect efficiency in maintaining normal body temperature of 101.0°F. under conditions prescribed in the Iberia Heat Tolerance Test.

In those cases in which two or more individuals or groups have the same heat tolerance co-efficient, the individual or group with the lowest average respiration per minute is considered the most tolerant as less effort was required in maintaining normal body temperature. An example of this is found in table 1. Both the ½ Brahman ½ Angus and the ⅜ Brahman ⅝ Angus have a co-efficient of 84. The halfbreds are considered the most tolerant in this case because their average respiration per minute was 55 while that of the ⅜ ⅝ crossbreds was 61 per minute. In the Iberia test, average respirations per minute is used in determining the position on the heat tolerance scale only in the case of equal co-efficients as determined from body temperatures.

As tests are made on larger groups of cattle and with added repetitions there will be some changes in the position of some of the groups in table 1. The scale given above is considered tentative but it is believed that the Iberia Heat Tolerance Test serves a useful purpose in classifying variously bred cattle as to their adaptability to tropical climatic conditions.

Literature cited

(1) Rhoad, Albert O. 1936. The influence of environmental temperature on the respiratory rhythm of dairy cattle in the Tropics. *Journ. Agric. Science*, Vol. 26 (1); 36-44.

(2)————1938. Some observations on the response of purebred *Bos taurus* and *Bos indicus* cattle and their crossbred types to certain conditions of the environment. *Proc. Amer. Society Animal Production*. 1938.

(3)————1940. A method of assaying genetic differences in adaptability of cattle to tropical and subtropical climates. *Empire Journ. Exp. Agric.*, Vol. 8, No. 31.

BIENNIAL BEARING IN CACAO

BY

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In this note an estimate is made of the extent of biennial bearing in cacao. Biennial bearing in any permanent crop implies a tendency for a year of high yield to be followed by a year of low yield and *vice versa*. This tendency may manifest itself in individual trees or in groups or populations of trees but is distinct from other non-alternate yield fluctuations whether characteristic of individuals or populations. It is presumably possible to extend the meaning of biennialism to include more complex periodic fluctuations in yield such as one or two years of high yield followed by two or one years of low. It is not, however, proposed to examine any but the strictly alternate tendency; it is evident from the data that the results of the analyses of the more complex forms are not likely to justify the analytical work involved.

The yield records of individual pickets have been kept for a field in Trinidad continuously for a ten year period (1932-3 to 1941-2). The field is comparatively young (27 years of age in 1941-2); it is uniform and situated on the Brasso Sand soil of the Montserrat district. The recorded section of the field consists of 570 pickets and from these 100 trees have been selected for study. The selected trees had to fulfil two requirements: (*i*) they must have given some yield in the first or second year; thus all non-yielders and trees that came into bearing during the period were excluded; and (*ii*) they must not have suffered serious damage or pruning or have become casualties during the period. The bulk of the sample, selected at random from the qualifying trees, consists of original trees although no specific age limitations were imposed.

The average yield of these trees was 2.73 lbs. dry cacao per tree per annum; there was wide variation about this mean, the standard deviation being 2.14 lb. or 80% of the mean. The total variation was first allocated as follows:

	d/f.	*S. squares*	*Mean square*
Total	999	4,589	
Trees	99	2,408	24.32
Years	9	405	45.02
"Error" .... (Trees × Years)	891	1,776	1.99

It can be seen from a comparison with the error variance that the variance due both to Trees and Years is highly significant. From the standpoint of isolating biennialism, the variation due to Trees is of no further interest; we will analyse the components of Years and Error (interaction of Trees and Years) both of which may contain biennial variation. The components are:

A. *Years*
(All components common to the whole 100 trees).
1. Seasonal fluctuations, (excluding A2 and A3).
2. Trend in yield over the ten year period.
3. Biennial bearing.

B. "*Error*"
(All components peculiar to individual trees and not common to all).
1. Error.
2. Differences in trend of individual yields over ten years.
3. Biennialism of individual trees.

Comments are perhaps necessary on some of these components: A2. The field being young, there has been a definite upward trend in yields over the period:

1932-3	2.69	lbs. per tree
1933-4	1.65	,, ,, ,,
1934-5	2.57	,, ,, ,,
1935-6	2.06	,, ,, ,,
1936-7	2.92	,, ,, ,,
1937-8	3.04	,, ,, ,,
1938-9	3.21	,, ,, ,,
1939-40	3.92	,, ,, ,,
1940-1	3.52	,, ,, ,,
1941-2	2.40	,, ,, ,,

This upward trend is of course included in the Years variation (A) but is distinct from purely seasonal fluctuations (A1) and biennial bearing (A3). If this trend is not calculated and allowed for, the extent of biennialism will be underestimated: the estimate of high followed by low and *vice versa* (biennialism) would then be made from data showing a tendency for low to be followed by low (at the beginning of the period) and high by high (at the end.)

B1. The error is of course the seasonal fluctuation due to differences in individual trees apart from differences in individual yield trends or biennialism.

B2. The remarks regarding A2 apply to individual trends. It should be noted that a downward trend in the yield of an individual decreases the estimate of biennialism in exactly the same way as an upward trend does. Indeed, any trend will decrease the estimate of biennialism in the individual tree unless it is calculated separately.

B3. The biennialism in individuals will exceed the average if all trees do not have the same peak years. The extreme example of individual biennialism would be when 50 of the 100 trees had their peak one year and the remaining 50 in the following year; under these conditions A3 would be nil and B3 would comprise the whole of the biennial variation.

The calculation of these components perhaps requires some explanation: the method of calculating the variation due to biennialism was by the regression of the yield in one year on the yield of the following year; thus, except for the first and last years, each yield was used twice, first as the dependent and then as the independent variable. This method gives only nine pairs for the ten year period, so that the resulting estimate of biennialism is on the average about one-tenth less than the true figure; no allowance has been made for this underestimation as being somewhat abstract and unnecessarily complicated.

The trends over the period were calculated by the regression of yields on years. These regressions were used to adjust yields for trends before calculating the biennial regressions.

In analysing the components of "Error" (B) the calculations were repeated once for each of the 100 trees; from the total of the variations thus obtained it was necessary to deduct the corresponding general effect of years (A).

The final analysis is as follows:—

	d/f.	*S. squares*	*Mean square*
Total	999	4,589	
Trees	99	2,408	
A. Years			
1. Seasonal	7	271	38.71
2. Trend	1	130	130
3. Biennialism	1	4	4
B. Trees × Years			
1. Error	693	1,279	1.85
2. Differences in individual trends	99	406	4.10
3. Individual biennialsim	99	91	.92

Neither of these biennialism variances is significant and it may be concluded that there is no evidence in the data of a biennial tendency. It should perhaps be pointed out that these trees are mature seedling stocks of mixed and unknown parentage. The fact that no biennialism is observed in the data does not necessarily imply that none will occur in uniform material of certain clones.

Acknowledgment

I wish most cordially to thank Mr. J. O. Irwin of the School of Agriculture, Cambridge, for examining the statistical methods employed in this note.

OIL FROM THE SUNFLOWER

There are probably few countries of the temperate regions which have a superabundance of fats and oils. War-time conditions, moreover, always accentuate any deficiency, and turn attention upon the possibilities of home production. A recent paper by E. F. Hurt (J. Roy. Hort. Soc., Vol. 68, No. 11) gives the results of experience with the sunflower crop. Oil from the seeds of this crop is useful for edible and culinary purposes for canning fish and making fine soap. Its gastronomic value is equal to the finest olive oil. The crop is widely tolerant of soil types, but removes large quantities of soil nutrients, most of which are retained in the stalk, and can be returned to the ground after harvest. Sowing the seed at an even depth of 1½-2in. appears to be important, and 7½ lb. of seed is needed to sow an acre by drill. Sunflower is a good cleaning crop, and appears to be but little affected by disease, though it is susceptible to wireworm attack and the depredations of birds at harvest time. Three semi-dwarf varieties "Mars", "Pole Star" and "Southern Cross" are suggested for Great Britain, and as the supply of fats and oils may be one of the most acute of post-war agricultural problems, the crop appears worthy of more extended trial. (*Nature*, Vol. 153, No. 3878, 1944).

SOME PROBLEMS OF CACAO FERMENTATION

BY

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Curing the cacao bean by means of fermentation is a long established practice and serves not only to remove the pulp which invests the bean but also to produce desirable changes in aroma, flavour and colour. There can be no doubt, however, that fermentation is also a very wasteful process. Many investigations have been made into the changes which the bean constituents undergo during fermentation, but practically all the results have been expressed on a percentage basis; this mode of expression does not necessarily give any idea of the absolute changes in constituents per bean since there is a concomitant loss of dry matter. The object of the present paper is to discuss the advantages and disadvantages of fermentation so far as present knowledge permits and to suggest the basis on which a new procedure might be developed.

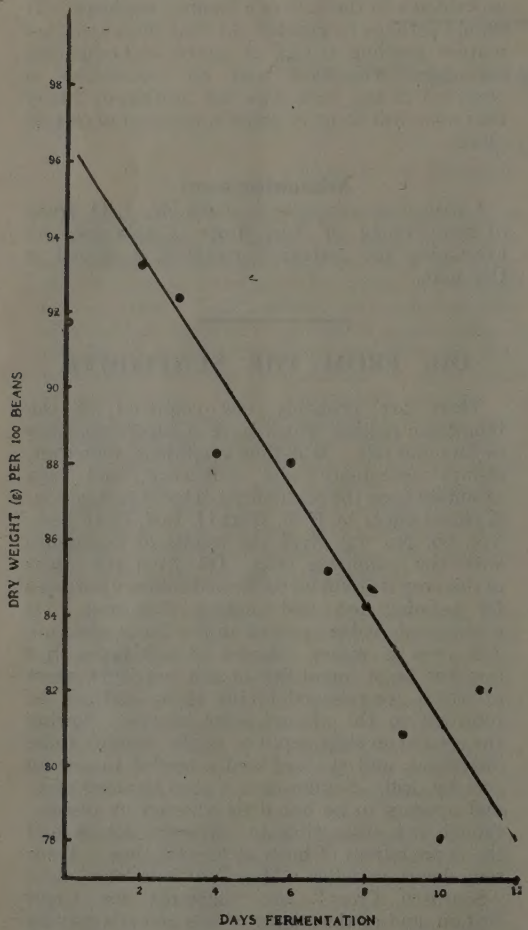

Fig. 1. The decrease in dry weight per 100 beans during fermentation calculated from the data of Birch (2). The equation of the line of best fit is $y=96.52-1.5432x$ ($r=-0.891$).

Absolute changes in dry matter

The changes in soluble and insoluble nitrogen of the cacao bean during fermentation were investigated by Birch (2). His experiments are of special interest because they were conducted on a sample basis and in this respect appear to be unique. Birch withdrew two samples of 100 beans from the sweatbox each day and determined the moisture content of a sub-sample. The data therefore provide means of estimating the dry matter per bean during successive days of fermentation. The changes in dry matter per 100 beans, calculated from Birch's data are shown in Figure 1 and it may be seen that the loss of dry weight during a 12 days fermentation is practically linear. The line of best fit for the data has been calculated and the equation is $y=96.52-1.5432x$ or in other words there is a loss of 1.54g. of dry matter per 100 beans per day. In seven days (the average duration of a fermentation in Trinidad) the loss per 100 beans is 10.8 g. or 11.2% of the original dry matter. This is a considerable loss and if a suitable alternative to fermentation could be devised which would eliminate this wastage, the planters' revenue would be correspondingly increased.

Relative and absolute changes in fat content

One of the arguments urged in favour of cacao fermentation is that it increases the percentage of fat in the bean. An example of this increase is shown in Figure 2 taken from the data of Humphries (4). The percentage increase is due to loss of various solids by diffusion from the bean, while probably little fat is lost by this means. By using the data of Birch (*loc. cit.*) in conjunction with those of Humphries (4) it is possible to obtain an estimate of the absolute changes in fat per bean during fermentation. It is permissible to combine the data of these two investigations since they were carried out under closely similar conditions. In Figure 3 are plotted the absolute amounts of fat per bean, after various periods of fermentation, calculated by referring the percentage fat of the bean (using smoothed values from Figure 2) to an absolute basis, using the calculated values from the equation given above. There appears to be a very slight increase in the amount of fat per bean during the first four days. It is doubtful whether this increase is significant although a slight synthesis of fat under the conditions of the fermentation is not impossible. After the fourth

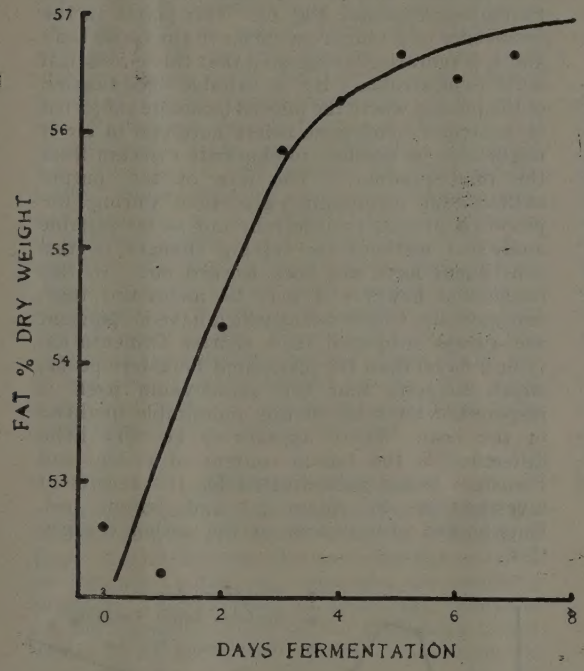

Fig. 2. The increase in fat, expressed as a percentage of the dry weight, during fermentation.

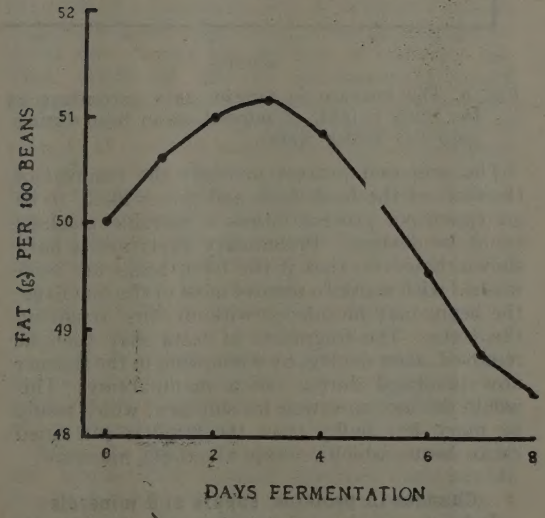

Fig. 3. The changes in fat per 100 beans during fermentation.

day, however, the amount of fat per bean declines steadily. Thus in a seven-day fermentation while an increase in the percentage of fat is obtained there is in fact a slight loss in actual amount of fat, either by diffusion or decomposition. It is to be expected therefore that if the fermentation process were eliminated there would be a slight net increase in cacao butter production.

Absolute changes in theobromine content

Several investigators have shown that the percentage of theobromine in the bean decreases during fermentation. Knapp and Wadsworth (7) record a decrease, expressed on a dry, fat-free basis, of 2.96% to 2.23% after eight days fermentation and Humphries (4) records a decrease from 2.88% to 2.20% in the same time. Calculating the latter data on an absolute basis gives a clearer idea of the extent of the loss of theobromine. The data are plotted in Figure 4. There is a loss of 0.543g. theobromine per 100 beans during a seven day fermentation or 40.5% of the amount originally present.

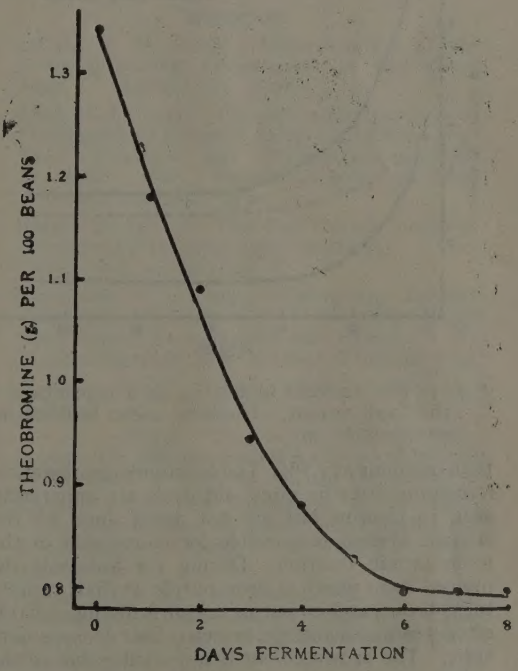

Fig. 4. The decrease in theobromine per 100 beans during fermentation.

Changes in tannin content

One of the desirable features of fermentation is that it brings about changes in the tannin which is present in appreciable amount in the cacao bean. This tannin is very astringent and it is no doubt largely responsible for the unpalatability of the raw bean. L-epicatechin, which has a bitter taste, also occurs though to a much smaller extent. During fermentation, the tannin appears to become

changed to brown substances ; the transformation is said to contribute to changes in colour and flavour (Knapp, 9). While this may be correct there appears to be very little experimental evidence in support.

It has recently been shown (Humphries, 6) that if fresh cacao beans, with testas removed, are finely minced and allowed to stand in air, the largest portion of the tannin fraction disappears in the space of one hour. A typical example of the behaviour is shown in Figure 5 where the changes in tannin with time as measured by cinchonine sulphate precipitate, total Stiasny precipitate and residual Stiasny precipitate are shown. The total Stiasny precipitate, which is thought to measure the total tannin (Humphries, 5), decreases from 6.0% in the fresh bean to reach constancy in less

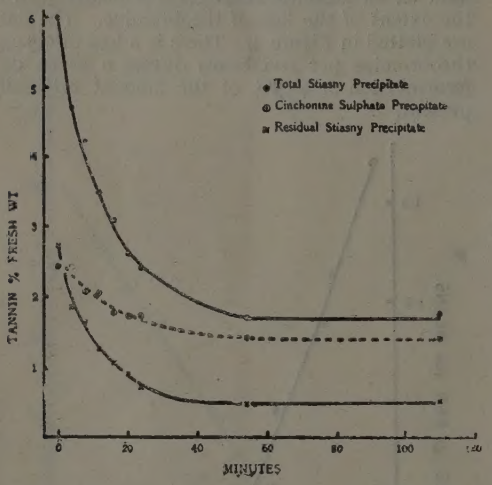

Fig. 5. The decrease in tannin, as a percentage of the fresh weight, of minced cacao bean during autolysis in air.

than one hour at 1.7%. The substance or substances remaining after 60 mins. autolysis are apparently akin to tannins but are not acted upon by the enzyme system responsible for conversion of the main tannin fraction. During the autolysis the minced bean which is deep purple at first, rapidly turns brown and no purple colour is distinguishable after 5 minutes and the brown colour deepens with time. The brown colour is apparently due to the polymerised tannin. It is suggested that this procedure may provide a basis for an alternative method of preparation of the cacao bean. The tannins of the bean are rapidly altered by the action of the natural enzymes present with the production of the desirable brown colours. Whether the flavour and aroma are altered at the same time is not at present known. The fact that the theobromine content is not reduced is probably not of great consequence since the alkaloid content of different kinds of cacao varies widely, so that a suitable percentage in the manufactured product could be attained by appropriate blending.

It was also shown (5) that if freshly minced beans were covered with water, an actual increase in tannin occurred (see Fig. 6). This points to the occurrence of a tannin-precursor in the cacao bean and it is tentatively suggested that this is identical with l-epicatechin. By a suitable modification of the process where the minced beans are subjected to anaerobic conditions before autolysis in air it might also be possible to eliminate catechin from the final product. The fate of the purple anthocyanin (cyanindin-3-glycoside) during the proposed process is uncertain and so far suitable analytical methods for tracing changes in this constituent have not been worked out. In this connection however it may be mentioned that, traditionally, Criollo beans which have no pigment are always subjected to a shorter fermentation (1 or 2 days) than the pigmented Forastero beans, which suggests that the anthocyanin itself is responsible for some of the undesirable qualities of the bean. There appears to be very little difference in the tannin content of Criollo and Forastero beans as indicated by the results of investigations by Adam (1) and Jensen (10). Unpublished observations of the author confirm this.

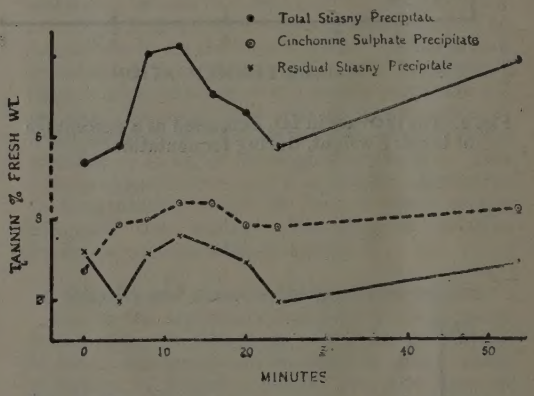

Fig. 6. The increase in tannin, as a percentage of the fresh weight, of minced cacao bean during autolysis under water.

The proposed process involves the removal of the testa of the fresh bean and this is likely to be an expensive process unless a suitable machine could be devised. Preliminary experiments have shown, however, that if the fresh beans are well-washed with water to remove most of the mucilage, the beans may be minced without first removing the testa. The fragments of testa may then be removed, after drying, by winnowing in the manner now practised during cocoa manufacture. This would produce an article for shipment which would be much less bulky than the familiar sun dried cacao beans which contain about 8% moisture.

Changes in proteins, sugars and minerals

It has been indicated that there is a considerable loss of dry weight during fermentation, most of the lost substance running away in the "sweatings"

which are not utilised in any way. Birch's data indicate that in an eight day fermentation the total nitrogen decreases from 2.07g. per 100 beans to 1.68g. per 100 beans. If all the nitrogen is assumed to be protein nitrogen and the total nitrogen figure multiplied by the conventional factor of 6.25 to convert to weight of protein, a loss of only 2.4g. per 100 beans out of a total dry weight loss of 10.8g. per 100 beans is accounted for. This figure will include the theobromine losses. From published analyses of the sweatings, *e.g.* Hardy (3), as much as 80% of the solids consist of reducing sugars due to direct loss of fructose and glucose present in the fresh bean and to sugars derived from the sucrose, starch and hemicelluloses hydrolysed during the acid conditions prevailing during fermentation. Mineral substances are also present in the sweatings but the extent of this loss is not clear from published results. The fresh cacao bean is rich in phosphates and loss of these may decrease the nutritional value.

Changes in vitamins

Today, when attention is directed towards the vitamin content of foods it would be desirable to know whether fermentation has a deleterious effect on vitamin content of cacao and the resulting product. There appears to be no data available on the vitamin content of the fresh bean but it would be an important point in considering the *pros and cons* of the fermentation process. It seems likely that the high temperature (maximum about 50°C.) attained in the first few days of fermentation would have a destructive effect on vitamins apart from the effect of the other somewhat drastic conditions, such as high acidity, which are set up in the fermentation. But apart from this possible destructive effect, the cacao bean actually gains in vitamins during the curing process. Knapp and Coward (8) have shown that the shell of a fermented bean is extremely rich in vitamin D, containing about 28 units per gram or about one quarter the potency of cod liver oil. They attributed this to irradiation of yeasts containing ergosterol during the sun-drying process. As the shell is removed during manufacture, this vitamin D is lost to human consumption although a small portion apparently permeates the fat of the cotyledons. Thus although the fermentation process is responsible for the bean acquiring an appreciable vitamin D content the advantage is outweighed by the fact that most of this is in the shell. Feeding experiments with cattle have shown that this cacao shell is suitable for use in small quantities but is toxic in large quantities because of the high theobromine content, so that the usefulness of cacao shell even as by-product is limited. No theobromine is present in the shells of unfermented beans.

From the above discussion it is apparent that the fermentation process involves considerable loss of potential revenue to the planter by loss of dry matter. Fermentation also involves loss of soluble substances from the bean and it is suggested that if these were retained the nutritional value of the cacao and products manufactured therefrom would be considerably enhanced.

Summary.

The advantages and disadvantages of the fermentation of cacao are discussed in the light of our present knowledge. Among the disadvantages are (1) considerable loss of dry matter, (2) loss of fat and (3) loss of proteins, soluble sugars, mineral salts and perhaps other substances of nutritional value such as vitamins. Among the advantages are (1) conversion of the tannin to brown substances with improvement of flavour and aroma, (2) decrease in the percentage of theobromine and (3) enrichment of the bean with vitamin D.

Manufacturers are unanimous in their preference for fermented beans and it is suggested that to overcome the wasteful nature of the traditional fermentation process an alternative process might be devised and one line of approach to the problem is suggested.

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WITCHES' BROOM DISEASE INVESTIGATIONS

VIII. Observations on Fan Broom Formation and Loss of Pods at River Estate from September 1942 to September 1943

BY

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The removal of fan and cushion brooms from the plot of 76 trees was continued for a fourth season, but by July, the incidence of the disease had become so severe that we were far behind with our monthly cutting schedule and the work had to be abandoned. To give some idea of the intensity of the disease on July 20th over 1000 brooms of all types were removed from Tree 1, in spite of the fact that it had been completely cleared of brooms two months before. The 1943 figures, therefore, comprise brooms removed from September 1942 to the end of the dry season in June 1943, and do not include the early wet season figures from July to September, which have appeared in previous years' results. The number of brooms removed is shown in Table I, and it is interesting to note the relatively enormous increase in the incidence of fan brooms, 18,034 being produced up to June 1943 against 10,253 for the whole of the previous season. The correlation that trees which produce many brooms one year do so again the following year was again very strong (total brooms r=0.85**, fan brooms r=0.83**, cushion brooms r=0.82**).

Table I

	1934-40	1940-41	1941-42	1942-43 (incomplete)
Total brooms	3901	12321	15612	25549
Mean per tree ...	51	162	205	336
Fan and Chupon brooms ...	1793	5616	10253	18034
Mean per tree ...	23	74	135	237
Cushion brooms ...	2108	6705	5359	7515
Mean per tree ...	28	88	70	99

By late 1942 and early 1943 it was felt that the disease must have about reached its maximum intensity at River Estate, being as far as we know, worse than anywhere else in Trinidad, and much worse than in the Sangre Grande and Marper areas which were previously considered to have been heavily attacked. Observers who have visited South America say that the intensity of the disease on River Estate is now comparable with what they have seen in Ecuador.

Little was done to control the disease during the year, except for the felling of certain heavily diseased fields near the experimental plots, with the result that at certain times, notably near the beginning of the wet season in July and again in November, large numbers of mushroom fructifications were formed. This resulted in an increase in pod infection from 10 to 44 per cent., in spite of the fact that again much of the crop was set during dry weather when conditions were not favourable for infection.

Pods have now been harvested in this plot for more than two years. Prior to January 1942 only full-sized pods were counted, but subsequently it was decided that all pods over 7.5 cms. in length would be counted. This was done for the following reasons. Firstly, it is obvious that if only 'full' pods are counted, many diseased pods may be missed because they have been destroyed by disease before reaching maturity; and secondly, Humphries (1) has shown that a pod 5 cms. long stands a good chance of escaping 'cherelle wilt', and one of 10 cms. is almost certain to survive and ripen if not destroyed by disease or eaten by animals, or birds. As, however, symptoms of witches' broom disease are found on pods of less than 10 cms. in length, the limit was fixed at 7.5 cms. Healthy pods were removed as they ripened, and diseased pods when they wilted or turned black, not when they first showed the symptoms of the disease. Altogether, from October 1942 to September 1943, 2519 pods were removed, of which only 576, or 23% were healthy, and 1104 or 44% were destroyed by witches' broom disease (Table II). Of the remaining 839 (33%) a few were destroyed by black pod (*Phytophthora palmivora*); a fair number by brown pod (*Botryodiplodia theobromae*) following injury by woodpeckers and squirrels; a few by anthracnose (*Colletotrichum* spp.) and others failed to reach maturity for physiological reasons. It is noteworthy that black pod disease is not common on this estate and was only observed in any quantity in the months of November and December.

The increase in the severity of witches' broom disease since 1942 is emphasised by the fact that from January to October 1942 only 10% of the pods harvested were destroyed by the disease, while from

Table II

Pods harvested

	Jan. to Oct. 1942	Oct. 1942 to Sept. 1943.
Total pods ...	1329	2519
Healthy pods ...		576
W.B.D. pods ...	127	1104
Other disease pods		839
% W.B.D. pods...	10	44

(1) Humphries, E. C. Studies in the Physiology of *Theobroma Cacao* with special reference to Cherelle wilt. *11th Report on Cacao Research* 1941-43: Govt. Printer, Trinidad, 1944.

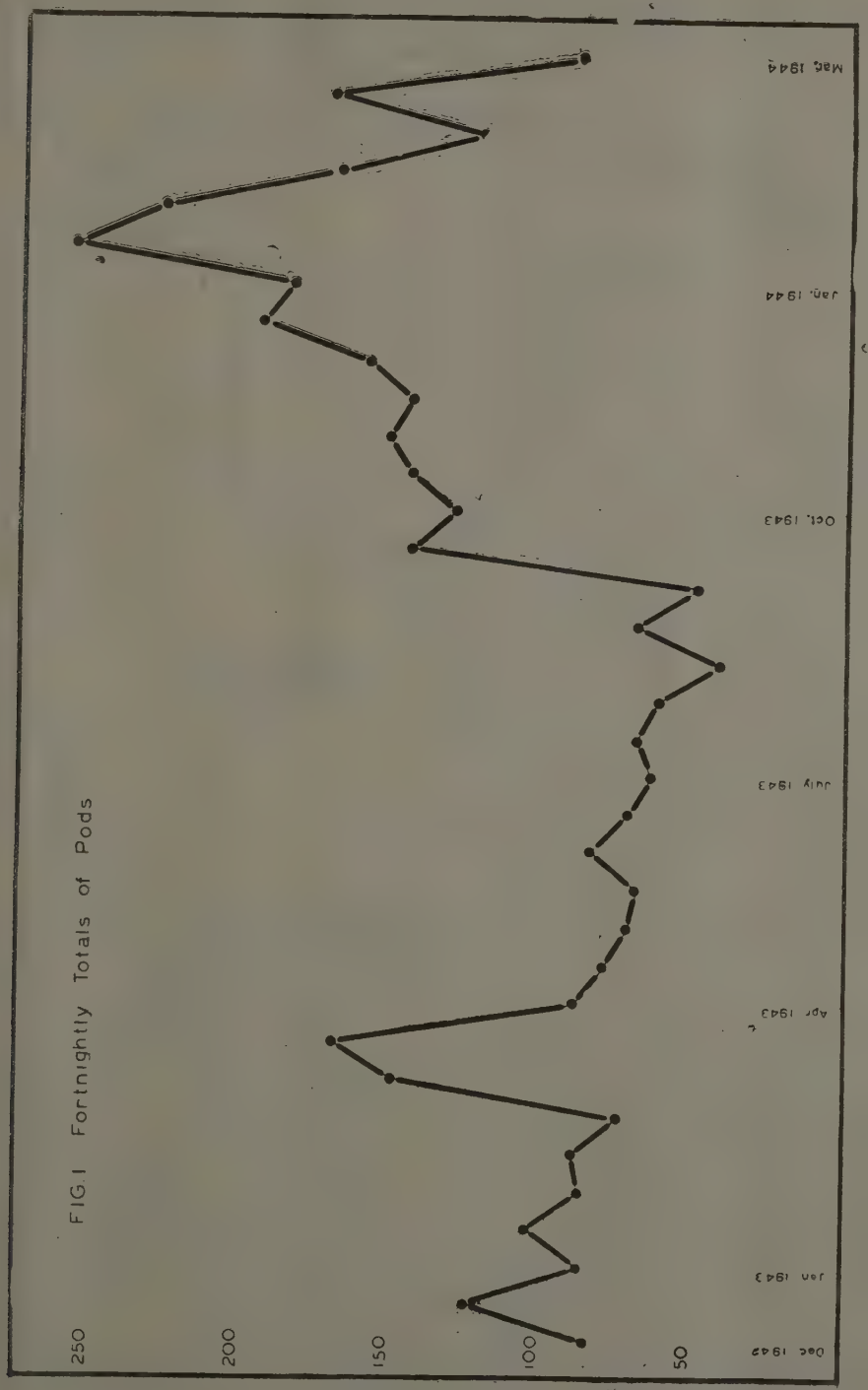

FIG. 1 Fortnightly Totals of Pods

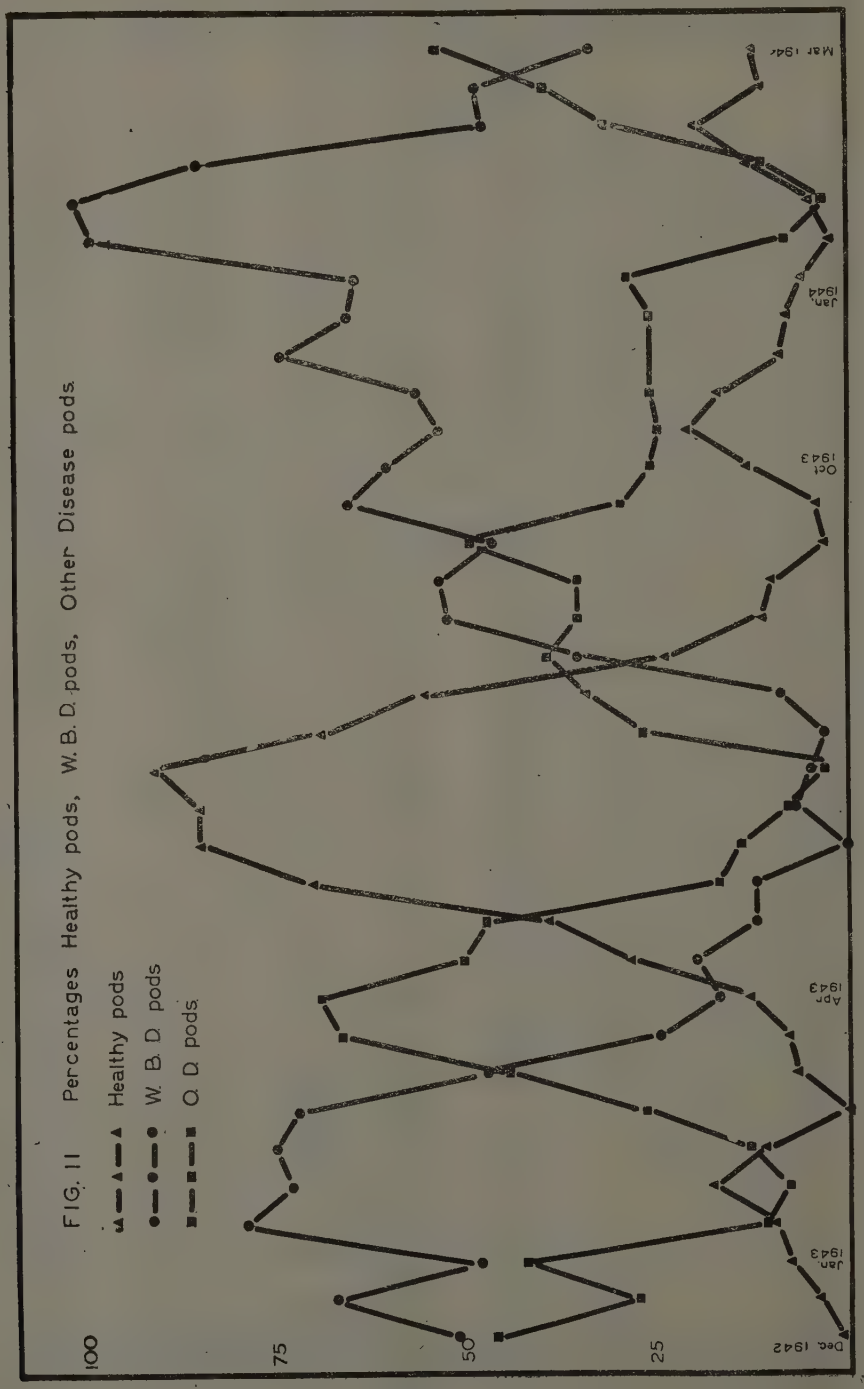
FIG. 11 Percentages Healthy pods, W. B. D. pods, Other Disease pods.
Healthy pods
W. B. D. pods
O. D. pods
100
75
50
25
Percentages
Dec. 1942
Jan. 1943
Apr. 1943
Oct. 1943
Jan. 1944
Mar. 1944
Date

October 1942 to September 1943 the percentage of diseased pods removed was 44%. Fig I shows the seasonal distribution of the crop and the percentages of healthy pods, witches' broom diseased pods and 'other disease' pods picked every two weeks since October 1942 are shown in Fig. II and Table III. Fig. I shows that never

Table III

Fortnightly totals of pods

Date	Total pods	Healthy pods	W.B.D. pods	Other disease pods	% W.B.D. pods
8/12/42	85	1	44	40	52
21/12/42	124	5	84	35	68
5/ 1/43	87	7	43	37	49
19/ 1/43	104	11	82	11	80
2/ 2/43	85	15	63	7	74
16/ 2/43	91	10	69	12	76
2/ 3/43	76	0	56	20	73
16/ 3/43	149	11	71	67	48
29/ 3/43	171	13	43	115	25
13/ 4/43	89	12	15	62	17
27/ 4/43	79	23	16	40	20
11/ 5/43	73	29	9	35	12
25/ 5/43	70	50	8	12	12
8/ 6/43	84	72	0	12	0
22/ 6/43	73	63	5	5	7
6/ 7/43	66	61	3	2	5
20/ 7/43	71	50	2	19	3
3/ 8/43	63	35	6	22	9
17/ 8/43	42	10	15	17	36
31/ 8/43	70	8	37	25	53
14/ 9/43	50	5	27	18	54
28/ 9/43	146	5	68	73	47
12/10/43	130	5	86	39	66
26/10/43	145	19	88	38	61
9/11/43	152	32	82	38	54
23/11/43	144	24	82	38	57
Totals ...	2519	576	1104	839	44

less than 40 and on only two occasions less than 60 pods were picked per fortnight, so that it is reasonable to calculate the results on a percentage basis. Table III indicates that pods picked during the latter part of the dry season and the beginning of the wet season usually escape witches' broom disease, but that pods harvested from August to March are mostly diseased. During 1943 the period of minimal attack when witches' broom diseased pods amounted to less than 5% occurred in the months of June and July (pods harvested at this time would have set from mid-January to March, the driest period of the year), and over 70% of the pods picked at this time of the year were healthy. The peaks in the 'other disease' curve which occurred in March-April 1943 and again in August-September 1943 were not caused by fungous diseases but by the wilting of pods for physiological reasons. It is considered that this severe wilting of large pods cannot be attributed to the normal shedding of the excess pods set on a healthy tree, but may be at least partially attributable to the large numbers of fan brooms and the consequent heavy trimming of small branches to which these trees have been subjected.

Table IV presents the individual yields of the 76 trees in this plot: percentages have not been calculated for trees producing less than 10 pods per annum. Although the percentage of diseased pods per tree varies from 15% to 71%, a close study of these figures does not indicate any evidence of resistance to witches' broom disease, pods on all trees appearing to be uniformly susceptible. This is in sharp contrast to fan and cushion broom formation where there is statistical evidence for resistance. The correlation between the percentage of witches' broom diseased pods produced in 1942-43 and the total number of brooms produced from 1939 to 1943 ($r=+0.17$) is low and not significant: it indicates that there is little or no relationship between the two sets of figures.

The lowest percentage of diseased pods recorded was from tree 17 (15%), closely followed by trees 24, 26, 32 and 47 with 16% and 17%. The trees which yielded the most healthy pods were Tree 21 (28 pods) Tree 2 (25 pods) and Tree 25 (23 pods). Table V shows the six 'best' trees which produced 15 or more healthy pods and had less than 25% witches' broom pods. It might be thought that these trees exhibited some 'resistance' but further analysis shows that of their healthy pods no fewer than 79% were harvested from May to August and were therefore set and matured at a time when infection by witches' broom disease was unlikely to occur. It is also evident that the heaviest *yielding* trees in the plot (*i.e.* those which have borne more than 50 pods during the year) bear all the year round and show a much higher percentage infection (Table VI). This apparent resistance therefore is nothing but disease avoidance. The lack of resistance can be further demonstrated in the following manner: a high and positive correlation co-efficient for the percentage of 'healthy' and 'other disease' pods for the whole year and the percentage of the year's pods set during the dry months and harvested in May, June and July would indicate a lack of resistance; in actual fact a correlation co-efficient of $r=+0.55^{**}$ was obtained.

An attempt has also been made to estimate the indirect loss of crop due to the severe fan broom attack and the consequent heavy pruning to which the trees have been subjected. Although certain of the weaker trees and especially those very susceptible to fan and cushion broom attack have undoubtedly been damaged and in some cases have ceased to bear, the remaining trees have produced 2519 pods in a bad year for cacao. Expressed in pounds of dry cacao per acre this is equivalent to 834 lbs. assuming of course, that every pod which reached a length of 7.5 cms. would have reached maturity had it not been attacked by disease. Moreover, if many of the trees had been severely damaged by fan brooms a considerable degree of negative correlation would be expected between total pods per tree and total fan brooms since 1939 per tree, but the calculated value of r is -0.043. Again it might be argued that a large number of pods would wilt after reaching a length

Table IV

1943

Tree No.	Healthy pods	Witches' broom disease pods	Other disease pods	Total pods	% Witches' broom disease pods	Tree No.	Healthy pods	Witches' broom disease pods	Other disease pods	Total pods	% Witches' broom disease pods
1 ...	15	67	41	123	54	40	16	48	14	78	61
2 ...	25	31	18	74	42	41	4	15	7	26	58
3 ...	15	7	11	33	21	42	18	13	32	63	21
4 ...	14	9	7	30	30	43	20	19	19	58	33
5 ...	3	29	25	57	51	44	1	5	2	8	—
6 ...	2	7	12	21	33	45	—	7	1	8	—
7 ...	7	7	10	24	29	46	—	1	2	3	—
8 ...	3	4	3	10	40	47	21	7	16	44	16
9 ...	—	—	1	1	—	48	20	33	16	69	48
10 ...	9	17	17	43	39	49	1	11	9	21	52
11 ...	—	—	—	—	—	50	1	7	5	13	54
12 ...	3	5	8	16	31	51	—	—	—	—	—
13 ...	—	—	2	2	—	52	15	22	15	52	42
14 ...	—	6	4	10	60	53	8	37	23	68	54
15 ...	5	19	9	33	57	54	6	20	7	33	61
16 ...	1	5	6	12	42	55	3	17	13	33	51
17 ...	8	5	20	33	15	56	12	39	21	72	54
18 ...	7	14	15	36	39	57	2	17	5	24	71
20 ...	3	12	4	19	63	58	2	3	—	5	—
21 ...	28	47	24	99	47	59	7	15	16	38	39
22 ...	3	10	3	16	62	60	2	7	1	10	70
23 ...	1	4	1	6	—	61	18	62	18	98	62
24 ...	15	6	15	36	17	62	21	28	46	95	29
25 ...	23	22	37	82	27	63	2	4	—	6	—
26 ...	24	8	19	51	16	64	—	10	10	20	50
27 ...	14	19	26	59	32	65	9	10	5	24	42
28 ...	2	5	6	13	38	66	4	7	2	13	54
29 ...	2	8	2	12	67	67	—	—	1	1	—
30 ...	1	7	2	10	70	68	6	7	15	28	25
31 ...	8	15	6	29	52	69	2	21	7	30	70
32 ...	19	7	16	42	17	70	5	5	12	22	23
33 ...	6	1	2	9	—	71	5	9	3	17	53
34 ...	6	7	11	24	29	72	19	38	28	85	45
35 ...	—	13	11	24	54	73	1	5	7	13	38
36 ...	12	24	4	40	60	74	5	20	25	50	40
37 ...	2	6	7	15	40	75	12	47	18	77	61
38 ...	—	5	4	9	—	76	15	20	1	36	55
39 ...	5	8	4	17	47	77	2	2	4	8	—
						Totals	576	1104	839	2519	44%

Table V

1943

Trees with over 15 healthy pods, under 25% W.B.D.

Tree No.	Total No. of pods	Healthy pods	% W.B.D. pods	No. healthy pods set in dry weather*	% healthy pods set in dry weather
3 ...	33	15	21	7	47
24 ...	36	15	17	14	93
26 ...	51	24	16	21	87
32 ...	42	19	17	18	95
42 ...	63	18	21	11	61
47 ...	44	21	16	17	81
Totals ...		112		88	79%

i.e. harvested in May, June, July and August.

Table VI
Trees with over 50 pods, 1943

Tree	Total pods	W.B.D. pods	% W.B.D. pods
1 ...	123	67	54
2 ...	74	31	42
5 ...	57	29	51
21 ...	99	47	47
25 ...	82	22	27
26 ...	51	8	16
27 ...	59	19	32
40 ...	78	48	61
42 ...	63	13	21
43 ...	58	19	33
48 ...	69	33	48
52 ...	52	22	42
53 ...	68	37	54
56 ...	72	39	54
61 ...	98	62	62
62 ...	95	28	29
72 ...	85	38	45
75 ...	77	47	61
	1360	609	45%

of 7.5 cms. on trees severely damaged by fan brooms, but this is not indicated by a correlation coefficient of r=+0.07 for fan brooms per tree and 'other disease' pods per tree. One is forced to the conclusion therefore that *up to now* (and it must be remembered that this is only the fourth year of serious attack) the trees themselves have been only slightly if at all damaged by the disease and their yielding capacity is virtually unimpaired. This raises the interesting possibility that a fan broom, which has plenty of leaves and chlorophyll, might be practically self-supporting as far as carbohydrates are concerned, and would only withdraw small quantities of minerals from the tree.

From these results there is no reason to suppose that trees of this kind of seedling cacao have any resistance to pod attack by witches' broom disease; all trees tested appear to be uniformly susceptible. Trees, however, which set the bulk of their crop in the dry season show considerable disease avoidance; as pods set from approximately mid-January to the end of April are unlikely to be attacked *under the conditions prevailing at River Estate*. Thus, if a clone which set its main crop at this time of the year could be found, its use might go far towards the economic control of the disease especially if such a clone exhibited resistance to fan-brooms and was not a free-flowering type which would be severely damaged by cushion-brooms. It is necessary, however, to consider such a suggestion with caution as our results do not suggest that trees which behave in this way are likely to be heavy bearers; indeed, it has been known to planters for years that a dry season crop alone or a 'late' crop is likely to be a 'short' crop, and that the trees which bear most cacao are those which bear all the year round. Therefore, although such a clone might be found (several I.C.S. clones show indications of behaving in this way) which might be of considerable value in areas where the disease is severe, it is unlikely to produce the high yields which are to be expected from the best of the I.C. Selections. Moreover, soil and climatic conditions vary considerably from place to place and a clone selected at River Estate might prove useless in, say, Sangre Grande or Rio Claro.

Some further observations on pod resistance of I.C.S. clones at River Estate will be published shortly in a later paper in this series.

WITCHES' BROOM DISEASE INVESTIGATIONS

IX. Loss of Pods at River Estate. Results to April 1944

BY

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Yield records in this field, which it had been hoped to continue to September 1944, were brought to an untimely end in April by the severe trimming to which the trees were subjected at the height of the dry season in an attempt to control witches' broom disease. Much of the branch crop was removed in the trimmings and many of the remaining pods failed to mature normally, the percentage of 'other disease' pods on 11th April, 1944 being 80%. It was therefore decided that the experiment should be terminated at once.

Tables IIa and IIIa do however confirm the previous season's findings that diseased pods are at a maximum in January and February (see also Graph I) and suggest that, although the 1943-44 season has produced a much heavier crop, witches' broom disease has been even more severe.

Individual tree yields are shown in Table IVa and the trees which produced over 50 pods in Table VIa for comparison with the 1943 results. Most of the trees which yielded well in 1943 have again done well, but there is still no reason to believe that any trees in this plot exhibit any resistance to the disease.

Table IIa

October 1943 to March 1944

Total pods	2151
Healthy pods	213
W.B.D. pods	1455
Other disease pods	483
% W.B.D. pods	68

Table IIIa

Date	Total pods	Healthy pods	W.B.D. pods	Other disease pods	% W.B.D.
7/12/43	159	14	119	26	75
22/12/43	195	16	129	50	66
4/1/44	186	11	123	52	65
18/1/44	257	4	231	22	90
1/2/44	228	12	210	6	92
15/2/44	171	22	131	18	76
29/2/44	122	24	59	39	48
14/3/44	172	19	84	69	49
28/3/44	90	11	31	48	34
Totals	1580	133	1117	330	71

Table VIa

Trees with over 50 pods 1944

Tree	Total no. of pods	W.B.D. pods	% W.B.D.
1 ...	73	36	50
2 ...	51	42	82
4 ...	50	32	64
5 ...	78	59	76
25 ...	105	47	45
26 ...	87	46	53
27 ...	70	42	60
42 ...	55	30	55
53 ...	77	65	84
56 ...	87	64	74
72 ...	122	75	61
74 ...	65	54	83
75 ...	59	44	75
	979	636	65%

Table IVa

Tree No.	Healthy pods	Witches' broom disease pods	Other disease pods	Total pods	% Witches' broom disease pods	Tree No.	Healthy pods	Witches' broom disease pods	Other disease pods	Total pods	% Witches' broom disease pods
1 ...	2	36	35	73	50	40	6	19	6	31	61
2 ...	6	42	3	51	82	41	2	36	10	48	75
3 ...	10	27	6	43	63	42	9	30	16	55	55
4 ...	6	32	12	50	64	43	1	6	9	16	37
5 ...	5	59	14	78	76	44	1	10	2	13	77
6 ...	3	10	3	16	62	45	—	10	—	10	100
7 ...	1	4	4	9	—	46	—	1	2	3	—
8 ...	3	4	6	13	31	47	3	17	6	26	65
9 ...	—	—	—	—	—	48	2	31	7	40	77
10 ...	—	5	4	9	—	49	1	10	4	15	67
11 ...	1	—	—	1	—	50	3	19	6	28	68
12 ...	1	9	2	12	75	51	—	1	—	1	—
13 ...	—	1	—	1	—	52	2	19	7	28	68
14 ...	1	9	4	14	64	53	—	65	12	77	84
15 ...	1	40	3	44	91	54	2	9	3	14	64
16 ...	—	8	12	20	40	55	2	20	10	30	67
17 ...	2	9	4	15	60	56	4	64	19	87	74
18 ...	—	2	1	3	—	57	4	33	1	38	87
20 ...	1	17	7	25	68	58	1	4	1	6	—
21 ...	5	35	3	43	81	59	3	16	3	22	73
22 ...	3	21	1	25	84	60	1	6	—	7	—
23 ...	1	2	—	3	—	61	10	24	13	47	51
24 ...	1	3	5	9	—	62	—	13	5	18	72
25 ...	17	47	41	105	45	63	2	17	2	21	81
26 ...	23	46	18	87	53	64	—	9	5	14	64
27 ...	3	42	25	70	60	65	1	9	2	12	75
28 ...	1	10	1	12	83	66	4	6	2	12	50
29 ...	1	15	2	18	83	67	—	—	—	—	—
30 ...	—	19	1	20	95	68	1	23	8	32	72
31 ...	5	34	4	43	79	69	1	19	4	24	79
32 ...	—	19	2	21	90	70	1	18	23	42	43
33 ...	4	1	1	6	—	71	2	8	—	10	80
34 ...	—	7	1	8	—	72	13	75	34	122	61
35 ...	1	17	1	18	94	73	1	9	3	13	69
36 ...	1	4	1	6	—	74	4	54	7	65	83
37 ...	1	10	6	17	59	75	6	44	9	59	75
38 ...	1	8	5	14	57	76	6	9	—	15	60
39 ...	2	29	2	33	88	77	1	9	2	12	75
						Totals	213	1455	483	2151	68%

EXPERIMENTS ON RIDGED CULTIVATION IN TANGANYIKA AND NIGERIA

The progress report for 1942-43* of the Lubaga Experimental Station, Shinyanga, Tanganyika, presented by Mr. A. N. Prentice to the Empire Cotton Growing Corporation contains some highly interesting observations on experiments comparing "ridged" with "flat" cultivation of maize and cotton. Since these observations are unlikely to be widely published, it is proposed to reproduce them here, together with some account of the present writer's own experience in the same matter in West Africa.

The relevant observations in the report are as follows:—

"Ridging" is more laborious than "flat" cultivation, but this year's results removed any doubts that may have lingered here as to its value. Tie-ridging is to become routine practice on Lubaga".

"Maize showed spectacular contrasts, although the general level of yield was not high. Differences between "flat" and ridging treatments were of the kind measured in multiples rather than percentages; "flat" was virtually a failure at 153 lb. grain per acre, and "large ridges" (5 feet), the best of the other treatments, yielded 1,120 lb. Tie-ridges (3 feet) were intermediate. (The treatment "large-ridges-tied", the practice at Ukiriguru, has unfortunately not been tried here but it is doubtless the best of all.) This trial completely reversed the wet 1942 season's results with cotton on the same site, when "flat" significantly outyielded the other treatments, but only by some 16% on the average, a small enough penalty to pay, in the occcasional year of waterlogging, for the benefits of ridging."

"Cotton, this year, gave results less spectacular than maize but still well in favour of ridging: "flat" yielded 611 lb. seed-cotton per acre, tie-ridges (3 feet) 845 lb. and "large" ridges 824 lb., "flat" being significantly below the others (difference for significance 119 lb. at P=.05)."

"Tie-ridging holds the rain where it falls, and the value of tie-ridging with small ridges doubtless lies in this and not in any remote property of the ridge. With "large ridges" the value on this shallow soil may lie partly in the greater (artificial) depth of soil available to the plant."

The most striking among these observations is, of course, the extraordinarily large increase in yield of maize in 1943 from ridging as compared with cultivation on the flat. The Nigerian Agricultural Department during the years 1922-30 carried out a number of experiments of the same kind, though never with such spectacular results as an increase of 600%. On the other hand, in all the Nigerian experiments a somewhat higher yield was obtained from ridging than from flat cultivation. What was perhaps even more convincing, was the fact that whenever different sizes of ridges were compared, a higher, though not necessarily a much higher, yield was invariably obtained from the bigger ridges than from smaller ones. This conclusion held good, not only in experiments with root crops like yams and sweet potatoes, for which ridging seems the obvious method of cultivation, but also for maize and cotton, which in many climates may reasonably be cultivated either on ridges or on the flat; it even also held good for groundnuts, a crop which a temperate climate farmer would hardly regard as one that needs to be ridged. The superiority of ridges was also found to hold good both on the experimental farms in the wettest part of the country, where the rainfall was of the order of 100 inches a year, and also on the driest farms, with only about quarter as much annual rainfall. (Naturally care was taken, when very big ridges were made, not to incorporate subsoil into the ridge).

Thus, in view of the Nigerian results, it is somewhat surprising to read that the Lubaga Station's yield of cotton on ridges in the wet year (1942) was less than the yield from the flat plots, even to the extent of 16%. One therefore wonders whether the "ties" mentioned in the report were possibly too high, perhaps nearly as high as the ridges. For if the ridges were "tied" only with small weirs (or "bars") in the bottom of the furrows, ridging could hardly cause waterlogging; and, in accordance with the writer's experience, such ridging might be expected to result in some increase of yield, as compared with the flat cultivation, even in a particularly wet year.

Ridging, or alternatively the making of mounds or hills, for most, or even all, crops is the practice of all the best agricultural tribes throughout all the varying conditions of soil and climate of different parts of Nigeria: it is, indeed, one of the most striking features of those traditional tribal practices. Moreover, whenever ridges are made, the little bars are made in the furrows (there is a special name for such a bar in many of the native languages). In view of these facts and of the Nigerian experimental results already mentioned and of those from Tanganyika which are quoted above, it would seem that one ought, in the tropics, to regard ridging as the normal practice rather than the reverse.

Mr. Prentice regards ridging as more laborious than "flat" cultivation. It is possible that this was only because the latter was what his labourers were used to. Nigerian labourers, who had been used from childhood to making hills or ridges, often suggested that they ought to have a smaller task when they had to undertake flat cultivation on experimental plots. They pointed out that on the flat cultivation system all the surface soil had to be moved, while on the ridged land, only a part is moved.

The use of "ridges and bars" or "tied-ridges" seems to have received much less attention by writers on anti-erosion measures than it merits. The explanation is possibly that ridges have been tried without the bars; and to make ridges without any bars at all is to do 95% of the work, but usually to miss, as regards erosion control, 95% of the benefit of the operation.

* Empire Cotton Growing Corporation. Progress Reports from Experiment Stations Season 1942-1943. Programmes of Experiments Season 1943-1944.

See page 122.

The advantage of accurately contoured ridging in controlling erosion has been demonstrated in numerous experiments, and is unquestionable. In this statement, however, the critical word is "accurately": for to make accurately contoured furrows on a slope that is at all irregular is a relatively difficult operation and a laborious one, too much so for an ordinary farmer; and the fact that the ridges are not parallel is a source of inconvenience, to say the least. If the contouring is not accurate, in other words if there is any appreciable fall along the furrows, then in the course of even one heavy tropical rain, much damage can be done, and the farmer making his first essay in erosion control will be correspondingly discouraged. But if little bars be built across the bottom of the furrows, then it is only necessary that the ridges should roughly follow the contours and they may therefore be parallel. The rate of flow of water along the bottom of the furrows can be controlled by increasing the number of bars to any reasonable extent. Indeed the writer is inclined to suspect that if in a given field, erosion cannot be controlled by means of roughly-contoured parallel ridges with bars, then the conditions in that field are such that no ridges, not even accurately contoured ridges will prevent the erosion, and resort must therefore be made to terracing in some form or other.

The value of little weirs made of stone, brush, wire netting or posts across fast running hillside open drains and runnels is well-known, and most workers must have used this device in some form or another. Bars or little weirs across the furrows in a field are equally important, unless each furrow is perfectly contoured: they serve the same purpose in controlling the stream running along the furrows. When a small shower falls, the bars hold it up entirely and prevent any flow of water. When heavier rain falls, the flow of water is restricted to the surface of the "stream", which has a relatively wide area; and the movement is correspondingly slower. It is of course as essential, in regard to bars in the field furrows, as it is in regard to a weir across a larger stream, that we should not ask more of the weir than can be borne by the bank or ridge. In either case, if we make our weir too high, a breach will occur in the bank, around one end of the weir. Possibly, in a theoretical sense, the exact height of the bar which may best be employed in any given field is a function of the nature of the soil and subsoil, of the maximum single rain storm that must be expected and of the maximum rate of rainfall that has to be expected. In practice, a bar about 5 or 6 inches high will be sufficiently satisfactory. The right frequency of bars is, however, a more important matter. So far as the writer knows no experiments or accurate measurements have ever been made by anyone on this point, but he judges, from experience, that trouble is liable to occur in a really heavy rain if the bars are spaced so widely as to give a vertical fall of more than about half an inch from one bar to the next: certainly the vertical fall from bar to bar should not exceed one inch. On land which is so steep that it is not possible to work to this rule, without getting the bars too close together, it will be necessary to sub-divide the field, so that the ridges may approximate more closely to the contours.

In working to this rule of under a vertical inch between bars, it is not suggested that the correct position for each bar, or even the required average interval, must be ascertained by the use of the staff and dumpy level. A little observation during the course of a heavy shower will give all the information necessary for practical purposes.

So far as the writer knows, there are only two possible objections that can be brought against the use of such bars. Of these one is the labour of making them. Where cultivation is being done by hand, there is no weight in this objection whatever, because the labour involved in making bars is relatively very small as compared with the labour of making the ridges. The other objection is also, in the writer's opinion of little practical importance. This objection to bars arises from the fact that the bars are naturally made after ridging is completed, and are therefore naturally made of material scraped up from the bottom of the furrows. The earth used to make the bars should therefore be sub-soil rather than soil. Therefore when, after an interval of one or more years, the ridges are split to make new ridges on the sites of the old furrows, part of the material in the bar is inevitably incorporated into the ridge. Thus, if the sub-soil is infertile, there is the theoretical objection that infertile material is being incorporated into the soil. This is however, a theoretical rather than a practical objection, because the volume of sub-soil thus incorporated into the ridge is, proportionately, very small. Possibly in some field experiments with very small plots, where everything possible must be done to maintain the uniformity of the plots, it might be worth while, before splitting ridges, to scatter the earth in the bars back along the bottom of the furrows where it came from. In ordinary farming practice this would be a quite unnecessary refinement.

The use of bars is open to much more objection where ridge cultivation is carried out with drawn implements than it is in hand cultivation. For when the furrows are "horse-hoed" and the ridges moulded up with the plough again after horse-hoeing, it is necessary either to lift the implements over the bars or else to make the bars up again after the cultural operations are completed. It is suggested that this difficulty need not entirely rule out the use of bars in implemental cultivation, provided that the ridges approximate fairly closely to the true contours, so that the bars need not be closely spaced. Even in cultivating with drawn implements, it will probably be found to be better to use a few bars, rather than to attempt to have the ridges so accurately contoured (and hence inevitably not parallel) that the fall along the furrow can be totally disregarded. As in most other cultural practices, the exact arrangement adopted in any particular field will depend on the judgment of the man who farms the field, making the best compromise he can between opposing considerations.

O. T. Faulkner

MANGANESE DEFICIENCY *

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Manganese deficiency has long been associated with alkaline rather than acid conditions in soils, and frequently occurs with boron deficiency in overlimed soils. Recently L. J. H. Teakle and A. S. Wild (1) have reported instances of manganese deficiency in lateritic soils in which grey speck disease in wheat and oats had appeared. That deficiency of manganese is not entirely controlled by soil pH is suggested by the observation that the critical pH for its occurrence varies within the range of one unit in different soil types. According to A. L. Prince and S. J. Toth (2) humic acid in soil mobilises manganese, and J. H. Hester (3) gives data showing a general parallelism between the organic matter content of soils and the amount of manganese taken up by crops grown in them. This is explained by the liberation of manganese from soil colloids by the carbon dioxide generated by the organic matter. Prince and Toth (2) postulated the presence in soil of ionogenic manganese complexes which are mobile and in which the manganese does not enter into base-exchange reactions. These complexes are assumed to be in equilibrium with exchangeable manganese in the colloid clay.

Seasonal variations in "easily soluble" (dilute acetic acid) manganese content of soils are examined by W. A. DeLong, A. J. Sutherland, and H. F. Salisbury (4) in Appalachian podsols. The proportion of easily soluble manganese is directly related to the rainfall. In this country R. L. Wain, I. V. Hunt, and G. C. Marsh (5) show that the manganese content of grass is highest in the period November-January and lowest in April-July. This is probably related to the observation that the incidence of grey speck disease in oats is greatest in warm dry spring weather.

Satisfactory control of manganese deficiency diseases is usually obtained by application of manganese salts at the rate of 14-30 lb. per acre (6). Spraying with 0.1 per cent. solution of manganese sulphate just before flowering markedly lowered the incidence of heart rot in peas (7). G. G. Taylor and M. M. Burns (8) report the elimination of a form of mottle-leaf, sometimes associated with deficiency of zinc, by spraying citrus trees with a manganese sulphate-lime preparation.

The sensitivity of different crops to manganese deficiency varies considerably. Thus in soils in which peas and clover grew normally, Adams (loc. cit.) (6) records that cereals showed deficiency symptoms unless a dressing of manganese sulphate was given. Marsh spot in peas is found by C. S. Piper (9) to appear when the manganese supply is sufficient to maintain vegetative growth but inadequate for normal seed production.

Within the plant system manganese probably activates the redox system, influencing both the oxidation of ammonia and the reduction of nitrate. This perhaps explains the beneficial effect of manganese on the intake of nitrogen by sugar beet. According to P. A. Vlasiuk (10), when nitrogen is supplied to the beet as calcium nitrate, manganese salts markedly increase both the weight of the roots and their sugar content. The direct relationship between the ascorbic acid and manganese contents of tomato plants, as noted by Hester (loc. cit.) (3), is also connected with the redox system. A review of the rôle of manganese in plant nutrition is given by R. W. G. Dennis (11).

(1) *J. Dept. Agric. W. Australia*, 1940, 17, 223; B., 1941, III, 61
(2) *Soil Sci.*, 1938, 46, 83, B., 1939 188.
(3) *Amer. Fert.*, 1941, 45, No. 7, 5; B., 1942, III, 45.
(4) *Sci. Agric.*, 1940, 21, 89; B., 1942, III, 43.
(5) *J. South-East Agri. Col., Wye*, 1939, No. 44, 114; B., 1939, 1273.
(6) E. Steenbjerg, *Tidsskr. Planteavl.*, 1939, 43, 819; B., 1941, III, 197. Teakle & Wild, *loc. cit* (1) A. B. Adams, *J. Dept. Agric., W. Australia*, 1938, 14, 283; B., 1939, 85.
(7) A. Ovinge, *Tijds. Plantenz.*, 1938, 44, 208; B., 1941, III, 40.
(8) *New Zealand J. Sci. Tech.*, 1938, 2, A, 115; B., 1939, 316.
(9) *J. Agric. Sci.*, 1941, 31, 448; A., 1941, III, 1084.
(10) *Compt. rend. Acad. Sci.* U.R.S.S., 1940, 28, 181, 184; A., 1941, III, 399.
(11) *Fert. Feeding Stuffs J.*, 1941, 26, 187, 205, 219.

* From *Ann. Repts. Soc. Chem. Indus., Prog. App. Chem.*, Vol. XXVI, p. 374.

USE OF CORN BINDER FOR HARVESTING FORAGE CROPS

According to the 1941-42 Report of the U.S.A. Agric. Expt. Station Report, Hawaii, a corn binder operated by a power take-off from the tractor was quite satisfactory for harvesting forage crops, including sorghum, pigeon peas and desmanthus as well as maize. It has been used successfully for cutting tall growths of Napier grass and Guinea grass yielding as much as 20 tons per acre. Certain mechanical and other adaptations desirable for easy harvesting of these two crops are suggested. Use of the combine for harvesting in the field is hampered by high rainfall and frequent showers.

The Editor is prepared to consider signed articles for publication in *Tropical Agriculture*. Such articles should normally vary between 1,000 to 6,000 words and may be illustrated if desired.

CHEMICAL NOTES

(Compiled by the College Department of Chemistry and Soil Science)

Factors Affecting Soil Colour

According to a Progress Report by M. J. Plice in the *Proc. Oklahoma Acad. Sci.* 23, 49-51 (1943) the most potent factors involved in soil colouration are iron and organic matter—particularly hematite and humic substances. The deepest reddish colours depend not only upon the degree of agglomeration of iron oxide but also on the size and denseness of iron oxide crystals, together with a paucity of humic substance. The lighter reddish and yellowish colours arise as iron oxide crystals size becomes smaller; hydration appears to be influential only indirectly. The various shades of brown are caused by varied proportions of small iron oxide particles and humic materials under fairly good drainage conditions. Gray shades in the near absence of organic matter (lake clay, glei, &c.) are mostly due to a ferroferri complex and not to ferrous iron alone. The most pronounced blue-gray soils seem to result when the proportion of ferri and ferro iron is approximately 2 to 3 or 3 to 2. The presence of highly dispersed, dehydrated (carbonized) organic particles in such soil produces a darkening in colour. With increasing organic content in the soil, a polyhydroxyphenolic pigment complex comes into prominence, according to degree of drainage. This is formed primarily from tannins, combined with ferri and ferro iron. This complex acts not only as an acid-base indicator but also as an oxidation-reduction indicator. In the acidic and better-aerated phase it is well exemplified by light brownish peats, &c. In the near-neutral to alkaline and more poorly aerated phase it is characterized by the dark to blackish coloured mucks and peats and black alkali areas.—(*Chemical Abstracts*, 1944, Vol. 38, No 7, April, 10, p. 1594).

* * *

B-Complex Vitamins in Sugar Cane and Sugar Cane Juice

William R. Jackson and Thomas J. Macek. —*Merk & Company, Inc., Rahway, N.J.*— Sugar canes vary greatly in sucrose content in different countries, in different parts of the same country, and from time to time in the same locality. The maximum sucrose content of Louisiana cane is usually about 12 per cent.; the average content of Cuban cane is between 13 and 14 per cent. In the present study the average sucrose content for the Louisiana samples was 11.5, and for the Cuban, 12.3 per cent. The bottom segments of the canes were generally richer in sucrose than the top segments. On the other hand, the top segments were generally richer in vitamins than the bottom ones. The results indicate that the vitamin content differs from one variety to another. This variation likewise occurs between the groupings of Cuban varieties; between these groupings, no uniform correlation was apparent in respect to sucrose and vitamin content. Except for pantothenic acid where the reverse is true, a comparison of the average vitamin values per pound sucrose shows that Cuban cane is richer in the B-complex vitamins than Louisiana. This was probably true because the Cuban samples were more mature than the Louisiana. Because of climatic conditions Louisiana cane is usually cut before it reaches full maturity. It is also evident that biotin and riboflavin occur in lesser amounts than does thiamine hydrochloride in sugar and juice, whereas niacin and pantothenic acid are found in greater amounts.—(*Indus. Eng. Chem.*, 1944, Vol. 36, No. 3, p. 261)

* * *

New Soil Fumigant

Preliminary tests have recently been made with a new soil fumigant known as DD Mixture; produced by the Shell Oil Company, DD is a mixture of 1, 3-dichloropropylene and 1, 2-dichloropropane obtained as a by-product in the manufacture of allyl alcohol from petroleum. Its value as a soil fumigant was first announced by Walter Carter (*Science*, April 23, 1943) after several years of trial at the Pineapple Research Institute of Hawaii. The preliminary report now available states that the efficacy of DD Mixture equals the best of other soil fumigants used in nematode control and surpasses them in at least three ways: (1) it is lower in price, offering for the first time a fumigant suitable for economical large-scale field use; (2) it is less dangerous and less obnoxious in use and in storage; (3) it is easier to apply. Further studies must define the various conditioning factors and their interrelations before all-inclusive recommendations for the use of this fumigant as a soil nematocide can be made.—(*Sugar*, 39, No. 4, 1944).

* * *

Environment Factors and Fertilizer Requirements of Sugar Cane

Studies made in Hawaii of the relation of environment factors and fertilizer requirements of sugar cane (*Hawaiian Planters' Record* 44, 1940, pp. 201-231, *ibid.* 46, 1942, pp. 17-36, 163-190, and 47, 1943, pp. 257-297) revealed that when the plant is in balance with its environment the total sugar in the sheaths of certain leaves is of the order of 10 per cent.; this is regarded as the primary index, and when that is normal, the plants are producing the maximum high-quality growth that can be expected of them under the climate in which they are growing. When the index rises, high qualities are obtained, but the total yield is low. When the index drops, poor quality results. Certain "secondary indices" should then be examined and the irrigation or manuring, or both, adjusted accordingly. "Through the use of this programme much of the guess work in crop management is eliminated. Economically, the programme pays for itself many times over in savings of fertilizers and water—not to mention the high yields of quality crops."—*Soils and Fertilizers*, Vol. VII, No. 1, 1944.